EBU - Tech 3335 : Methods of measuring the imaging performance of television cameras for the purposes of characterisation and setting

Alan Roberts, November 2016

SUPPLEMENT 20: Assessment of a Blackmagic Design URSA Mini 4.6K camera

Tests have been conducted in line with EBU R.118. This document is a report of the results of the tests defined in Tech3335 and is not an endorsement of the product.

This is a report on the performance of an URSA Mini camera, serial number 2786620, provided for testing by Blackmagic Design. The menu listings and test results are derived from a later test on an updated camera.

The single sensor is specified as super35mm format with at least 4608x2592 photo-sites, and Bayer pattern filters. Super35mm in video cameras is usually 23.5x13.2mm, making the individual photo-site dimensions about 5.1µm square, a little larger than in a conventional 3-sensor ⅔" HDTV camera, thus the sensitivity ought to be about the same (F11~F12 at 2000lux). There are two versions, for EF or PL mount lenses. The EF version was tested, with a Zeiss 100mm lens. The PL version has a 12-pin connector for PL and B4 lens control.

It can record in many modes, from full 4608x2592 down to 1920x1080, at the usual range of frame rates – 23.976, 24, 25, 29.97, 30, 50, 59.94 and 60 fps. Bit rates run from 513Mb/s down to 5.6Mb/s all for 30fps. The highest standard format uses ProRes 444 or DNG format. There is no QuickTime decoder for ProRes 444 in Windows, and Blackmagic recommend using the DNG format, with all decoding done in Da Vinci Resolve. However, Grass Valley have recently released an upgrade to Edius which bypasses QuickTime, so that all the ProRes formats can be handled properly. Testing used a mixture of formats and decoding approaches.

The camera body weighs about 2.35kg without attachments and measures at 135x230x150mm overall, although the specification is in imperial units and includes a side handle at 5lb and 7.61x8.23x5.78 inches. It runs on 12v supply with standard V-lock battery mount, via 4-pin XLR, and there is a 4-pin XLR power output socket on the right side. Power consumption is not specified (nor is the acceptable range of input voltages, except in the listing of sockets deep in the user manual where it states 12~20 volts) but the supplied external power supply was rated at 12v 8.33A, i.e. 100watts.

There are three BNC connectors on the back: 12G SDI in, 12G SDI out, Ref/TC in, and SID out on the right side. There is also a 3.5mm headphone jack, and built-in stereo microphones. Two XLR sockets for audio in are on the top under a flap, and there are LANC connectors for remote control. There is a US port for updating the software.

There is a monocular viewfinder as an accessory. The fold-out touch-screen LCD panel is 5" diagonal, 1920x1080, and is the only way to control the camera menus. There are individual rotary volume controls for Left and Right, and two C-Fast card sockets.

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Many of the menu items have little or no effect on image quality. Those that have significant effect are highlighted. The full set of menu items is given for completeness. In boxes with a range of numeric settings, e.g. -99~+99, the values indicate the range, and zero means no alteration to factory setting, not zero effect, and no scales are given in the manuals. For each item, the factory setting is underlined. Menus are nested: items in italics in the listing are headings leading to a further nested menu. The menu structure and contents has changed between the first test (April 2016) and the later test (November 2016), and so it is logical to expect that there may be future changes – and therefore this listing is only a snapshot.

Settings are only starting points, recommendations. They should not be used rigidly: they are starting points for further exploration. However, they do return acceptable image performance.

Measurement results are given in section 3, after the menus. Measurements were made according to the procedures set out in EBU Tech.3335.

This listing of the menus and contents is complete, but this should not be used as an excuse for not reading the manuals.

1 Controls and menus

1.1 Control buttons

Outside, on the back of the LCD panel

Item	Description
Iris	Press for Auto Iris. Use Forward/Reverse to set manually
Focus	Press for Auto Focus
F1	Function buttons
F2	
Rec	Start/Stop recording
Playback	Start/Stop clip playback. Press Rec to return to camera
Forward/Reverse	Skip clips on playback, or iris control

Inside, on the camera body

Item	Description
Iris	Press for Auto Iris. Use Forward/Reverse to set manually
Focus	Press for Auto Focus
Peak	Press for Focus Peaking
PGM	Toggle between Camera video and 12G SDI Input
Rec	Start/Stop recording
Playback	Start/Stop clip playback. Press Rec to return to camera
Forward/Reverse	Ski clips on playback, or iris control
Menu	Press for the menus
Power	Power on/off
L	Audio volume controls
R	

Side handle

Item	Description
Iris	Press for Auto Iris

Focus	Press for Auto Focus
Rec	Start/Stop recording

1.2 Touch-screen controls

Across the top Tap an icon to get control

Item	Range	Description
		On-screen markers etc
Zebra	Off, On	
	75 ~ 95 ~ 100%	Slider or tap to select
Focus assist	Off, On	
	Low, Medium, High	
Frame guides	Off, On	
	4:3, 14:9, 16:9, 1.85:1, 2.35:1. 2.39:1, 2.4:1	Slider or tap to select
Grids	Off, On	
	Thirds, Crosshairs, Center dot	Not exclusive, you can have the lot
FPS	23.98, 24, 25, 29.97, 30, 50, 69.94, 60	Slider or tap to select
Off speed	Off, On	
Off speed frame rate	12 ~ 24 ~ 60[1]	
Shutter	11.2, 15, 22.5, 30, 37.5, 45, 60, 72, 75, 90, 108, 120, 144, 150, 172.8, 180, 216, 270, 324, 360°	
(flicker-free)	90, 180, 360°[2]	
Auto exposure	Off, On	
Iris	F2 ~ F22[3]	Slider or tap to select
Auto exposure	Off, On	
	Shutter, Shutter+Iris, Iris+Shutter[4]	
Duration display	Shows length of recorded clip	
ISO	200, 400, 800, 1600	Camera gain. Ref level is ISO 800
WB	Bright sun (5600), Incandescent(3200), Fluorescent n(400), Mixed (4500), Cloud (6500)	White balance
Adjust	10,000 ~ 5,600 ~ 2,500	Slider or tap to select, changes to CWB
Tint	-50~ 10 ~ +50	Cyan/Magenta shift
Power	Reports power status	

Across the bottom Tap an icon to get control

Item	Range	Description
Histogram		Goes away if 'Codec and Resolution' selected, see Monitor settings
Record	Start/Stop recording	Flashes if frames are dropped
Card indicators	Shows availability and time left	Tap to bring up card menu
Card menu		Report on and format cards
Audio meters		Tap to bring up volume controls

Anywhere else on-screen Tap an icon to get control

Item	Range	Description
Zoom		Double-tap and drag to zoom in/out
Full-screen		Swipe up/down to clear/return indicators

1.3 'Dashboard' menu contents

Menu settings Access by menu button, Submenus are indented.

[1] The maximum frame rate depends on the recording resolution and format. Usually 60fps, but down to 40 for 4k DNG files or up to 120 for HD.
[2] Flicker-free shutter speeds depend on frame rate, this list is for 25fps and changes when fps is changed.
[3] These are the iris limits for the Zeiss 100mm lens used for the tests.
[4] Shutter+Iris adjusts shutter first, then iris if the shutter range does not have enough range. Iris+Shutter does iris first then shutter.

RECORD 1

Item		Range	Description
Codec and Quality	RAW	Lossless, 3:1, 4:1	RAW is Cinema DNG. DNxHR was not selectable in the tests
	ProRes	XQ, 444, HQ, 422, LT, PXY	
	DNxHR		
Resolution	4.6k (4608x2592), 4.6k 2.4:1 (4608x1920), 4K 16:9 (4096x2304), 4K DCI (2096x2160), UHD (3840x2160), 3kAnamorphic (3072x256, 2k 16:9 (2048x1152), 2k DCI (2048x1080), HD (1920x1080)		

RECORD 2

Item	Range	Description
Dynamic range	Film, Video[5]	Gamma curves, no control options
Window sensor	Off, On	Use full sensor or windowed part[6]
Project frame rate	23.98, 24, 25, 29.97, 30, 50, 59.94, 60	
Off speed recording	Off, On	Over/under cranking
Off speed frame rate	12 ~ 24 ~ 60[7]	In integer steps
Preferred card for recording	Card 1, Card 2, Fullest Card	
RAW recording on 2 cards	Off, On	Disabled unless RAW selected[8]

RECORD 3

Item	Range	Description
Timelapse	Off, On	
Capture one frame every	2 ~ 10 frames, 1 ~ 10, 20, 30, 40, 50 sec, 1 ~ 10 min	
Detail sharpening	Off, On	Applies only to ProRes recording and SDI output
Detail sharpening level	Default, Medium, High	
Stop if card drops frame	Off, On	

MONITOR 1

Item	Range	Description
LCD, Front SDI, Main SDI		Identical options for all three
Clean feed	Off, On	Toggles all screen info except record tally
Display 3D LUT	Off, On	
Zebra	Off, On	
Focus Assist	Off, On	
Frame guide	Off, On	
Grid	Off, On	Default is Off for SDI
Safe area guide	Off, On	
False colour	Off, On	Use colours to code video levels[9]
All		
Frame guides	4:3, 14:9, 16:9, 1.85:1, 2.23:1, 2.39:1, 2.4:1	
Guide opacity	25, 50, 75, 100%	Set opacity outside the guide area
Focus assist	Peak, Coloured lines	Peak is less obtrusive
Focus assist level	Low, Medium, High	
Focus color	Black, Red, Green, Blue, White	
Zebra levels	75, 80, 85, 90, 95, 100%	

MONITOR 2

[5] Setting Cinema DNG forces Film mode. Video mode is claimed to be 'similar to REC 709'.
[6] 'Windowed' avoids scaling in the camera but reduces the resolution and increases aliasing, while allowing higher frame rates.
[7] Off speed maximum rate depends on resolution and recording format.
[8] Recording to both cards together allows higher frame rates.
[9] False colours: Purple=black, Blue-near black, Green=mid-grey (18% reflectance), Pink=+1 stop (skin), Yellow=>80%, Red=>95%.

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Item	Range	Description
LCD		
Text surrounds image	Off, On	Zooms display to show text outside image
	Meters, Codec and Resolution	Meters=histogram/audio meters
Screen brightness	0 ~ 50 ~ 100%	
Front SDI, Main SDI		Identical options for both
Status text	Off, On	Clear text from outputs
Display status for	Cinematographer, Director	Controls: FPS, Cam, Operator, Duration, Reel, Scene, Take, Dynamic range, Timecode
SDI output	2160, 1080p, 1080i[10]	
All		
Grids		
Thirds	Off, On	
Crosshairs	Off, On	
Center dot	Off, On	
Safe area guide	0 ~ 90 ~ 100%	In steps of 5%
Anamorphic desqueeze	Off, On	Makes all images 2.4:1

AUDIO 1

Item	Range	Description
Audio input	Camera, XLR	
Camera		
Camera internal mic	0 ~ 50 ~ 100%	
Speaker volume	0 ~ 50 ~ 100%	
Headphones volume	0 ~ 50 ~ 100%	
Low-cut filter	Off, On	
Level -15dB pad	Off, On	
XLR		
Headphones volume	0 ~ 50 ~ 100%	
Speaker volume	0 ~ 50 ~ 100%	
Channel 1 input	Line, Mic	
Channel 2 input	Line, Mic, Use Ch 1	

AUDIO 2

Item	Range	Description
XLR		
Channel 1 gain	0 ~ 50 ~ 100%	
Channel 2 gain	0 ~ 50 ~ 100%	
Channel 1	Low, High	Pre-amp gain
Channel 2	Low, High	Pre-amp gain
Ch 1 phantom power	Off, On	48v
Ch 1 phantom power	Off, On	

SETUP 1

Item	Range	Description
Date and time	Set all	Goes to another menu
Language	English	Only English for now
Shutter measurement	Angle, Speed	Speed was not selectable in the tests
Flicker shutter based on	50, 60Hz	Changes shutter speed options
Battery display	Percentage, Voltage	
Time code drop frame	Off, On	Only relevant for 23.98, 29.97, 59.94fps

SETUP 2

Item	Range	Description
ATEM camera ID	1 ~ 99	
Color bars	Off, On	100% bars.[11]

[10] SDI output can also be 2160p in UHD, 1080i is available only at 50, 59.94, 60fps rates.

Headset mic	0 ~ 50 ~ 100%	
Program mix	0 ~ 100%	Camera/talkback mixture
Reference source	Internal, Program, External	Genlock source
Reference timing	Lines 0 ~ 10, Pixels 0 ~ 1 ~ 2749	

SETUP 3

Item	Range	Description
Set function button		
F1, F2		Same choices for both
Behaves as	Preset, Up/down, Toggle on/off	F1 default=Toggle False color LCD F2 default=Toggle Display LUT LCD/Main SDI
Setting	Fps, Iris, WB, ISO, Shutter	
Parameter	…	Parameter depends on 'Behaves' and 'Setting'
Parameter displayed on	LCD, Front SDI, Main SDI	This is only for 'Behaves' as 'Toggle on/off'

SETUP 4

Item	Range	Description
Door LED	Off, On	LED on the LCD door
Door LED brightness	Low, Medium, High	
Factory reset	RESET	
Hardware ID	4C06B0C9	Reports, no control
Software	4.0	
Playback	All clips, Single clip	

PRESETS

Item	Range	Description
Create presets using current settings, or import from a card. Add, edit, delete etc		

LUTS

Item	Range	Description
Select, import, export, edit, delete lookup tables		
	Blackmagic 4.6k Film to video	Supplied with the camera

[11] These are ordinary vertical bars. SMPTE or ARIB would have been much more useful. I could not find a way to record colour bars, the recorded file showed only full-screen black.

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2 Measurements

All measurements were made on frames captured in the camera onto a C-Fast card. Live viewing and monitoring was done using a Blackmagic Pocket Ultrascope, monitoring only the HDSDI feed. Clips were ingested into Edius and/or Da Vinci Resolve and extracted as TIF or BMP files for use in this document. This process avoided any image scaling. Gain was applied as necessary in order to explore the dynamic range.

The camera serial number was 2786620. The lens was a Zeiss Makro Planar 100mm F/2 serial number 15906596. I shall use the EBU system of designating scanning standards (e.g. 25i is what is commonly called 50i).

2.1 Colour performance and Infra-Red response

A standard Colorchecker chart was exposed, using tungsten illumination and the camera balanced to tungsten. Fig 1 shows the results for Video modes, HD and UHD. Performance is the same, as expected. Overall, the colouring is rather lurid. Skin tones are rather too pink, while all other colours with significant red content (orange, violet, salmon pink, purple, light orange, red and yellow) are all too bright and pink. The cyans are too bright. The grey scale is correct, so this is not a colour-balancing problem. Clearly, all pictures from this camera will need post-production grading to improve the colour performance.

Figure 1 Colorchecker, Video mode
a) HD **b) UHD**

The camera responds to infra-red, not excessively but enough to cause problems. It could well be that it was infra-red which caused the pinkness seen in this test, but that seems unlikely since the grey scale is correctly neutral. The camera could benefit from having an infra-red stopping filter fitted. Fig 2 shows an IR LED in a TV remote control (about 930nm radiation) showing magenta.

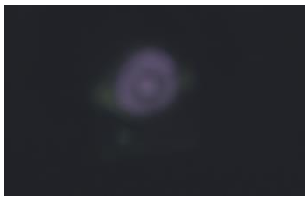

Figure 2 IR response

2.2 Gamma curves (opto-electronic transfer characteristic) and Dynamic Range

Multiple exposures of the Colorchecker chart, using shutter and aperture to control exposure, provided many exposure levels from which it is possible to extract the curves from the grey scale patches. It is not clear from the camera specification whether the recorded signals are coded to ITU Rec.601/709 formula, or sRGB. On test, on the initial assumption that the video signals would be 601/709, negative values were measured as

well as above peak white. Values below zero ought not to happen since the ITU 709 gamma curve is not specified below zero. Therefore, I have assumed that all signals are sRGB coded in Film and RAW modes, but ITU 601/709 in Video mode, since that is how the footage captured will be used..

Fig. 3 shows the curve for Video modes, recorded in ProRes HQ, ISO800. The full plot (Fig. 3a) shows an apparent-near match to the standard ITO.Rec.709 curve (the plotted line), with a soft knee such that the peak of the coding range is achieved at about 1 stop of overexposure. The fine detail plot (Fig. 3b) shows points not fitting the Rec.709 curve.

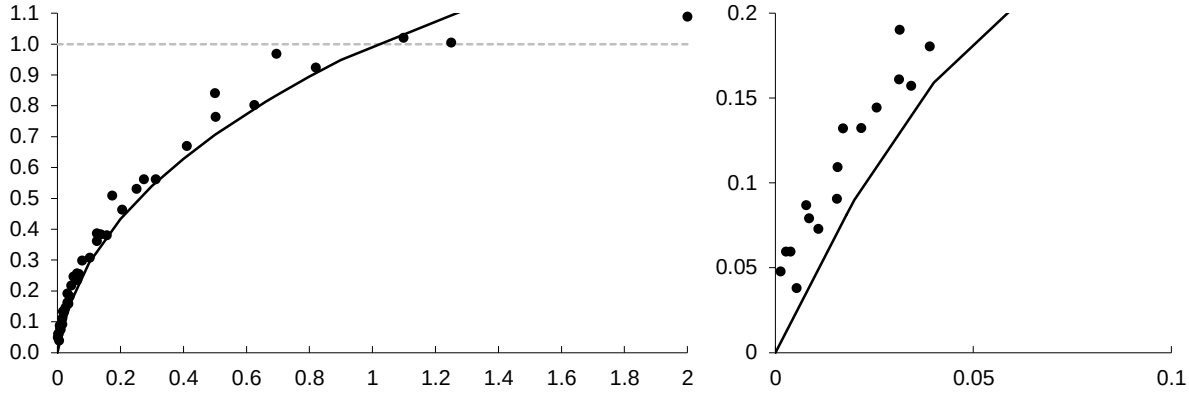

Figure 3 Gamma curve, ISO800, Video mode, ProRes HQ, linear axes
(a) Full range **(b) Detail near black**

The dynamic range in Video mode appears to be about 1,000:1, 10 stops, maybe a little more.

Fig.4 shows the curve for Film mode, with logarithmic axes. It is clear that there is little or no headroom as such, and the dynamic range is not significantly more than about 1,000:1, 10 stops. The video coding appears to be conventional Rec.601/709.

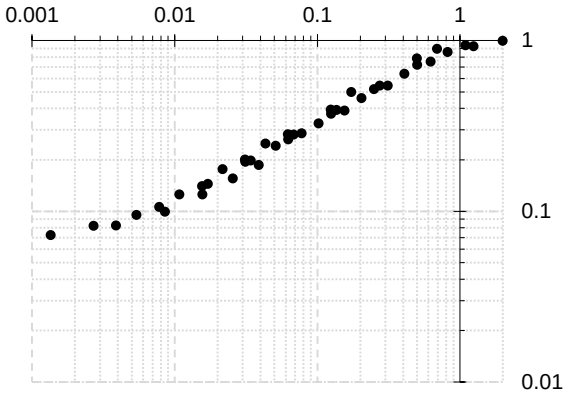

Figure 4 Gamma curve, ISO 800, Film mode, ProRes HQ, logarithmic axes

The sory is rather different in RAW recording mode.

Fig. 5 shows the Film-mode curve in RAW recording mode. I have adjusted the horizontal axes of the log plot such that the curve is more-or-less linear below unity exposure. This gives about 3 stops of headroom, and the curve flattens out at around 0.001 resulting in an overall range of about 8,000:1, 13 stops. Thus there appears to be little difference between ProRes and RAW

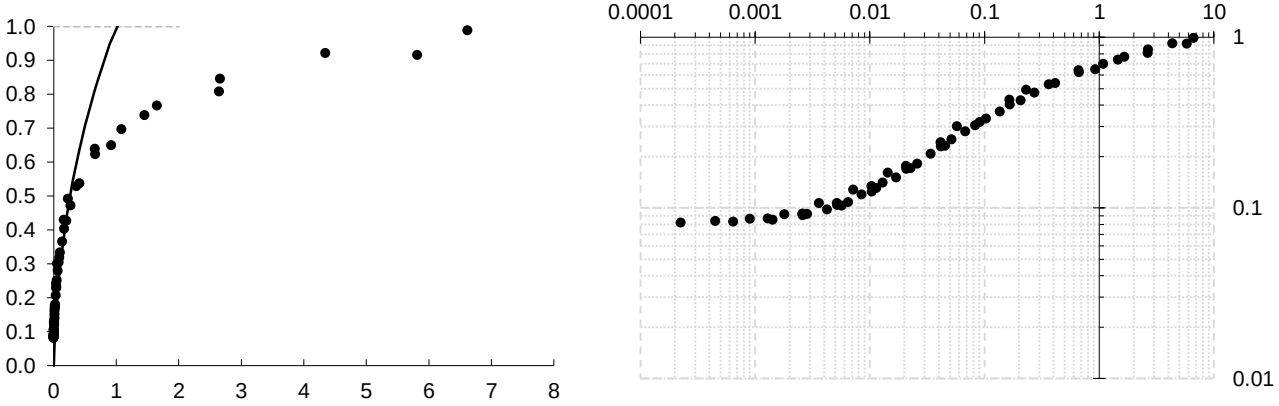

Figure 5 Gamma curve, ISO800, RAW 4:1
(a) Linear axes **(b) logarithmic axes**

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recording, as far as dynamic range is concerned as determined by these measurements.

The human eye is rather better at extracting detail from dark signals than these measurements indicate; close examination of the individual clips confirmed the dynamic range to be about 1,000:1 (10 stops) for ProRes HQ Video, but couild be up to 8,000:1 (13 stops) for ProRes HQ Film mode, at ISO800. Simliar examination of the captured clips showed the dynamic range for RAW 4:1 UHD to be about 20,000:1 or 14.2 stops. Outside ths range, either the white patch on the Colorchecker is clipped, or the black patch is indistinguishable from the surround material. These have to be the limiting factors.

2.3 Resolution and aliasing

Measurements were complicated by a characteristic of the camera; the framing changes with recording mode. In ProRes mode, the image can be derived either the whole sensor (keeping the lens angle constant), or as a 'Windowed' image taken from a cropped section of the sensor giving 1:1 pixel mapping between the photo-sites and the video signal. RAW recordings are always 'Windowed'.

Since the tests used a fixed lens, this meant adjusting the camera distance for some changes of setting. The usual HD zone plate test chart was designed to fill exactly the width and height of the image, but making it fit exactly half the image width makes it work perfectly well for UHD as well.

2.3.1 Resolution and aliasing, HD

Tests were made at ISO800 and about F/8, using ProRes recording. Fig. 6 shows one quadrant of the luma part of the chart, with Image Sharpening off, in Video mode, both Windowed and not-Windowed. The smaller quadrant (bottom right) explores UHD resolution.

Clearly, the resolution is better if Windowing is switched off. This is hardly surprising since in the Windowed mode, and area of the sensor exactly 1920x1080 photo-sites is used, while in non-Windowed mode the whole sensor is used via a scaling algorithm which works quite well. The Windowed version clearly shows coloured aliasing, the result of using too few photo-sites for the output resolution. The level of aliasing is quite low, indicating that there might be an optical low-pass filter in the camera, but this would be aimed at the UHD resolution, so does not help much with HD performance.

There is only one control in the camera which affects image quality – Detail Sharpening. Fig. 7 shows the range of settings for Video mode (it is not available in RAW recording, and is not advisable in Film mode since it is always better to tweak pictures in post-processing). The Default setting is quite good, with a fair

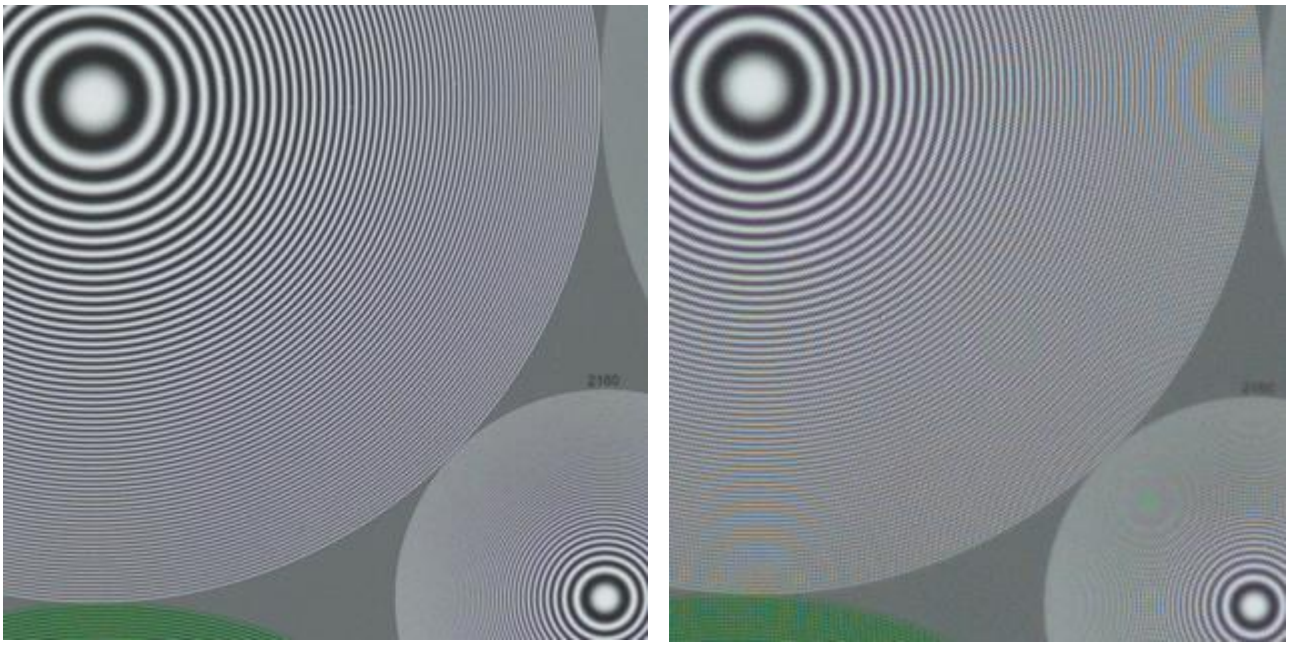


Figure 6 Zone Plate, HD ProRes HQ, Video mode
(a) Not windowed **(b) Windowed**

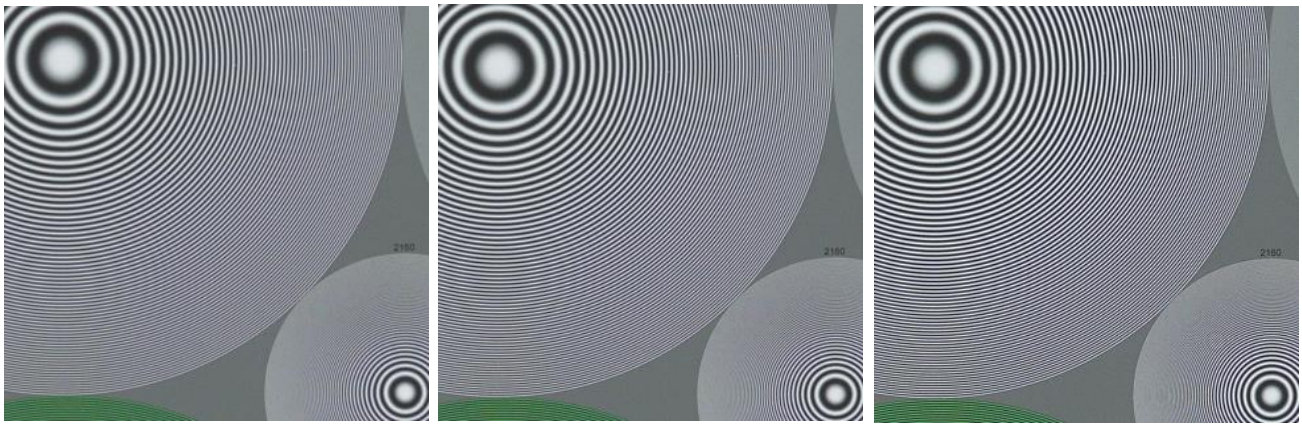


Figure 7 Detail Sharpening, HD, Video mode, ProRes HQ
(a) Default setting (b) Medium setting (c) High setting

balance between increased resolution and aliasing. The Medium setting introduces some significant aliasing, and the High level is unacceptable for high-end broadcasting.

2.3.2 Resolution for '4k' (UHD-1 3840x2160)

The HD zone plate chart was reframed so that it filled exactly half the frame. Thus it fully explored UHD resolution, and the smaller quadrant bottom right explores 7680x4340.

Detail Sharpening is available in UHD as well, and the images are always windowed, so only 3840x2160 photo-sites are used for UHD. Fig. 7 shows the luma quadrant for UHD.

With Detail Off, the resolution is exactly the same as for HD Windowed. This is because the image shown here is from exactly the same-sized area of photo-sites, and thus it is no surprise that Detail Sharpening produces heavy aliasing. The Default setting is acceptable, but the higher settings should be avoided if at all possible.

The level of coloured aliasing suggests that there is probably no optical low-pass filter, and that resolution is being limited only by the lens. This is particularly clearly demonstrated in the smaller quadrants, where thers is obvious frequency content above UHD limits.

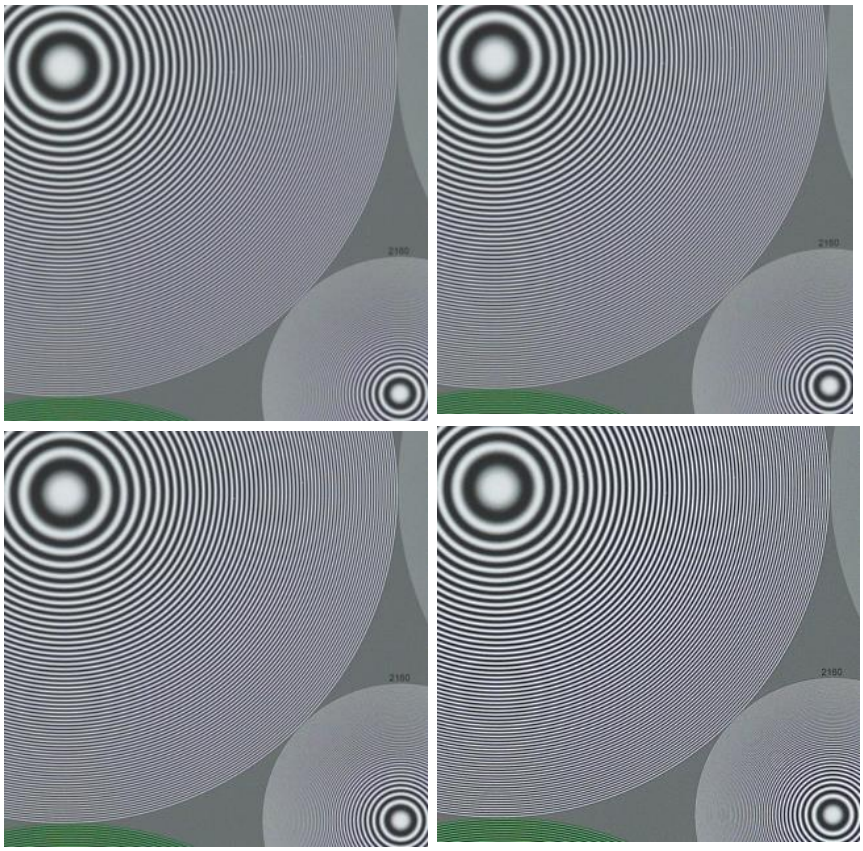


Figure 8 Zone Plate, UHD, Video mode, ProRes HQ
(a) Detail Off (b) Detail Default
(b) Detail Medium (d) Detail High

The resolution in RAW recording mode (lossless compression) is exactly the same for both HD and UHD, because HD is always formed from a smaller part of the sensor, Windowed. Fig. 9 shows this clearly. For this figure, the clips were decoded in Blackmagic Resolve, and exported as 16-bit TIF files. Coloured aliasing is clearly visible and could be a problem with motion-sensitive coding such as MPEG. It is

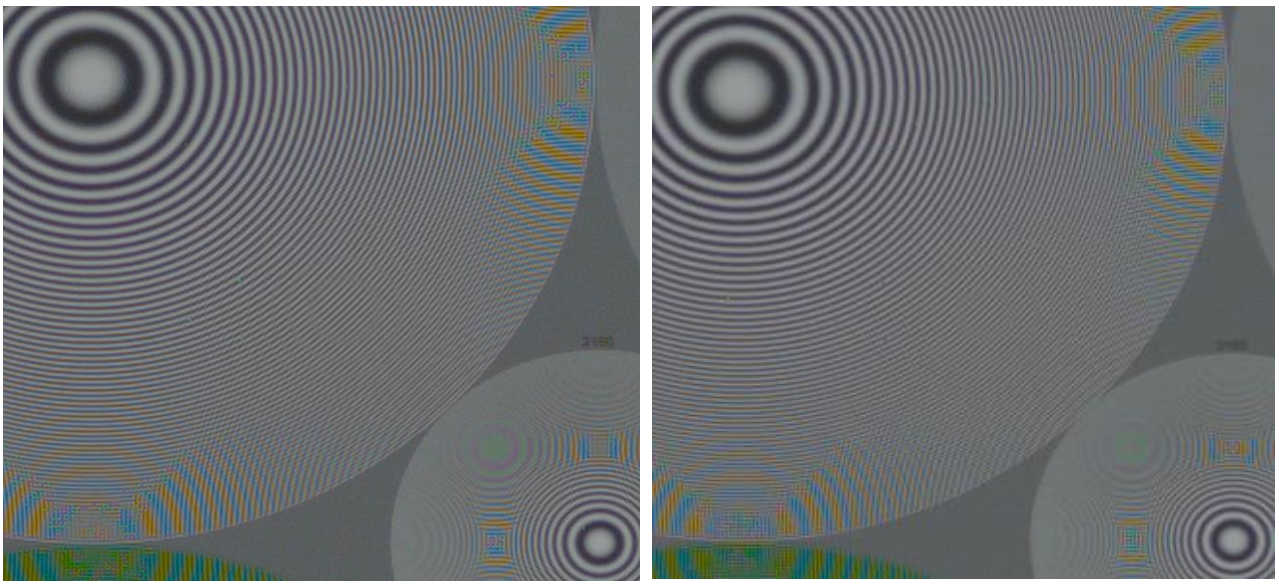


Figure 9 Zone Plate, RAW 1:1 mode
(a) HD **(b) UHD**

interesting that this aliasing is not visible in ProRes recording, perhaps indicating that either the Bayer-pattern decoding is better in the camera, or that the ProRes coder has a spatial filter to remove it.

2.4 Noise

2.4.1 Noise profile

The multiple exposures of the Colorchecker chart used to derive the gamma curves also returned noise measurements. Fig. 10 shows the distribution of PSNR (Peak Signal to Noise Ratio) with video level, at ISO800 with ProRes HQ recording.

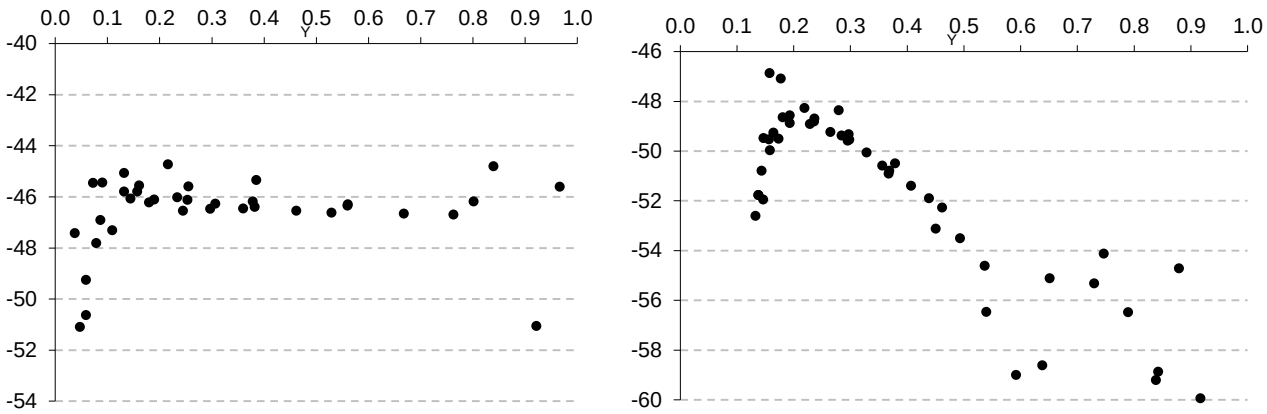


Figure 10 Noise profile, HD, ProRes HQ
(a) Video mode **(b) Film mode**

For Video mode, the distribution is substantially flat between 10% and 100%, which is rather unusual. The drop towards black is frequently seen in all-digital cameras, because the major source of noise is the detected photons themselves, so-called 'shot-noise', and thus noise is proportional to signal level. The noise level at mid-grey (50%) is about -46dB, not reaching the figure EBU R.118 of -48dB for HD Tier 1, but exceeds the -44dB figure for HD Tier 2.

For Film mode, the steady drop towards peak white (100%) is reminiscent of older cameras. There are no values below 10% simply because the video level never drops that far, even with extremely low exposure. At mid-grey, the noise level of -54dB easily meets the R.118 criterion of -48dB, but the images need major post-production to make them acceptable, and this will raise the noise levels, probably near to that for Video mode.

Fig. 11 shows the noise profile for RAW recording. This follows more-or less the same curve as for film mode, and is the same for both HD and UHD (because both modes are effectively windowed, using 1920x1080 or 3840x2160 areas of the sensor), and there is little advantage in using lossless compression.

The curve does not meet the R.118 criterion of -50dB at mid-grey for UHD, but just meets the -48dB for HD Tier 1. In this respect, RAW is more noisy than ProRes HQ, which is a surprise. It indicates that after the inevitable post-processing that RAW recording needs, noise levels may be worryingly high.

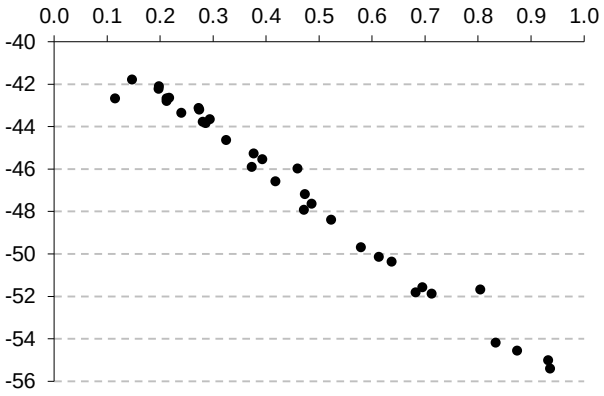
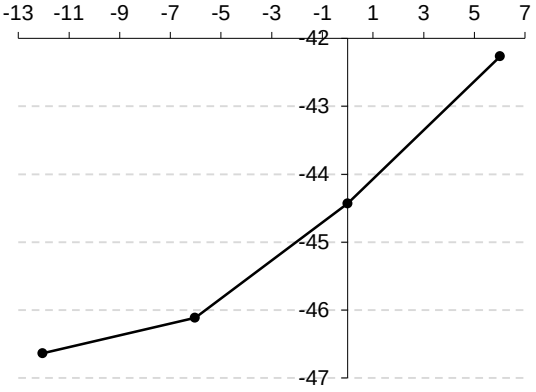


Figure 11 Noise profile, RAW 4:1

2.4.2 Noise change with ISO setting

The camera was exposed to a Kodak Gray card, lit to produce 50% brightness level on a video monitor, and measurements taken with ISO settings from 200 to 1600. At each setting, the lens aperture was adjusted to keep the signal level constant

Fig. 12 shows the results for HD mode. The horizontal axis is the equivalent, in dB of gain, of the range of ISO settings, thus ISO200 is about -12dB, ISO 1600 is about +6dB gain.



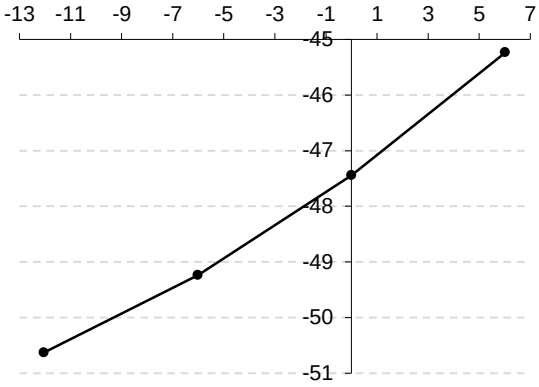


Figure 12 Noise change with camera speed setting
(a) Video mode, ProRes HQ **(b) RAW 1:1**

Normally, the noise level should rise by 3dB for each change in gain of 6dB, a linear slope of 0.5. For Video mode, the noise rises from -46.64dB to -42.26dB resulting from a 18.06dB gain change, so the slope is 4.37/18.06 about 0.242. This indicates that there is a noise floor at the lower ISO speeds, not permitting the noise levels to drop as expected. The rising slope at high 'speeds' also indicates that there is no noise-reduction in this camera.

For RAW lossless mode, the slope is about 0.3. This indicates that there is no noise reduction in the camera, which is a shame because the noise levels are all rather high, but that RAW recording can produce lower noise levels than ProRes HQ. However, it is likely that the post-processing needed to deal with the RAW mode will raise noise levels to levels similar to that of ProRes. Thus, only at ISO400 could the camera qualify for R.118 tier 1.

2.5 Sensitivity

In a television camera, sensitivity is normally defined as the lens aperture required to produce 100% peak white from a white card with a reflectance of 90%, lit by 2000 lux. This usually assumes a standard setup condition of either no gamma-correction or a curve which follows the normal equation, i.e. without a knee, and with interlaced scanning using 1/50 exposure interval. Since even the video mode appears to have a knee, reaching peak white is not a good prospect. Therefore, the camera was exposed to a Kodak Gray card, 18% reflectance, and the aperture at which it reached 50% video level was recorded. The same exposure should produce 100% video from the 90% white side of the card and thus is a fair representation of the sensitivity.

At ISO800 with 180° shutter, the nominal camera settings, 50% video level from the grey side of the card was at F/6.7. For comparison, the typical figure for a ⅔" 3-sensor HD video camera is F/11 ~ F/12, about 2 stops more sensitive. There was no difference between HD and UHD, or between ProRes and RAW recording.

2.6 Motion portrayal

The sensor is CMOS, which can be read either by scanning or by instantaneous transfer into a readout store. Scanning produces the so-called 'rolling shutter' effect. The simple test for this is to use a small desk fan, and to adjust the clockwise rotation speed such that strobing holds the blades almost stationary. Then, if the sensor is being scanned, the down-ward moving blade will be widened and the upward-moving blade narrowed. The effect is made much more visible by using a short shutter.

Fig. 10 shows still frames, using 11.2° shutter. The distortion is fairly severe, and is normal for a rolling-shutter camera.

Figure 3 Fan, Video ProRes HQ

3 Conclusion

The camera specification tells little of its performance. The sensor size is not stated (beyond it being super 35mm), the gamma curves are not defined, neither is sensitivity nor power consumption nor the coding equations. This made the testing unusually difficult and time-consuming. The confusion caused by the scant specification approximately tripled the time it took to test the camera.

There are very few controls which affect image quality.

The active sensor area has at least 4608x2592 photo-sites (total 11,943,936), which is more than enough for good performance at HDTV, and possibly even for UHD. The image dimensions are unstated in the manual and specification, but the super-35mm format in video cameras is generally accepted to be about 23.5x13.2mm, so the photo-sites are must be spaced at about 5.1µm, meaning that the photo-site area cannot be greater than 26 μm^2, compared with 5µm and 25μm^2 for a conventional ⅔" camera. However, the camera appears to be about 2 stops less sensitive than a conventional 3-sensor camera.

Resolution and aliasing at HDTV are quite good, although some high-frequency content pollutes the HD image as aliasing. At UHD, resolution falls a little short of the target, which is inevitable unless the sensor were to have significantly more photo-sites; coloured aliasing is visible both vertically and horizontally although the level is not particularly high.

The colour performance is rather lurid, with a distinctly pink look to many colours, and the camera responds to infra-red. These conclusions may be related to each other. The performance is reminiscent of cameras having the colour matrix after the gamma correction, which is the wrong way round for best performance.

The dynamic range is about 14 stops using RAW mode, rather less in ProRes HQ recording.

Noise levels are consistently higher than is acceptable for EBU R.118 tiering at the highest level. In Video mode, it could qualify for HD Tier 2. Even so, the unusual colour performance requires considerable grading. In Film mode, the noise levels are lower, and at ISO settings up to 400 the camera could qualify for UHD Tier 2 or HD Tier 2L/2J, but the inevitable post-production grading to improve colour performance is likely to raise the noise to unacceptable levels. This implies that the camera is not really suited to broadcast use without careful grading and noise reduction.

The sensor is evidently scanned, the so-called 'rolling shutter' effect. Rotating motion is very poor.